METHOD AND DEVICE FOR DESIGNING A DATA NETWORK

Field of the invention

5   The present invention refers to a method and a device for designing a transport network.

Background art

According to conventional communication network design methods, an optimum design of a network is conducted only
10   when a new network is planned for the first time. During the design process, path and link capacities of a network are designed for a given specific traffic demand. For a given predetermined demand pattern an optimisation of the network design is conducted, and an optimum network
15   minimizing the cost is designed. Afterwards, as the demand pattern changes from the pattern considered during the initial planning phase, it is likely that the efficiency of the network decreases day after day.

In actual telecommunication networks, indeed, the
20   demand pattern varies very frequently, depending upon changes in client subscriptions or changes in traffic load due to the widespreading of new communication services or the introduction of new techniques.

It follows that, in a conventional network, forecast
25   of the demand is hardly possible. Moreover, in multimedia networks of recent years, demand forecast has become more and more difficult.

Currently, the re-design of computer networks, particularly wide area networks, is a complex procedure
30   requiring specialist trained staff. For a nation-wide network, it may take a specialist several weeks to design and simulate an alternative network architecture.

Very often, as the traffic demand increases in correspondence of a particular path or node of a network, a network administrator/operator intervenes simply adding new apparatuses, in order to solve the problem very rapidly. As

5 a consequence the network configuration, as well as the architecture of single nodes, grows in an irregular, confused and very expensive way.

In US 6,223,220 a method of designing a computer network is disclosed making use of an object-based computer

10 representation which allows on-screen linking of a service object, representative of a network service, to site objects representative of physical sites on a wide-area network. The user specifies expected traffic demands between the sites, and an algorithm calculates a physical

15 connectivity map representative of proposed hardware circuits linking physical sites.

The method disclosed in US 6,223,220 analyses the network under known traffic conditions, for determining a network configuration which is optimised for those

20 particular conditions. The network optimisation obtained is therefore strictly connected to a particular traffic condition, representative of a past traffic flow, and does not derive from a forecast of possible future traffic flows on the network.

25 The Applicant has tackled the problem of designing or optimising a transport network, or even a single network node, in order to satisfy an estimated future traffic demand on the network, with particular attention to realization and reorganization costs. To this purpose a

30 network design and analysis method allowing to evaluate the flow's cost for different network structures is described.

In the following the term "flow" is intended as the allocation, on a transport network system, of an amount of structured bandwidth.

The Applicant observes that one of the main goals when

5 a telecommunication network has to be planned or optimised, is to understand which is the best topology to adopt in order to satisfy the traffic demand and, preferably, to save money.

The Applicant is of the opinion that, since one would

10 hardly know how the traffic demand will evolve in a network, it would be useful to a network administrator/designer to have a methodology able to show, for different network topologies, the probability to satisfy client's needs.

15 In view of the above, it is an object of the invention to provide a network design and analysis method and device allowing to evaluate the flow's cost for different network topologies, allowing to understand which is the best configuration or evolution for the network under study.

20 **Summary of the invention**

According to the invention that object is achieved by means of a method and a device for designing a transport network, the network having a plurality of network elements and a plurality of connections connecting the elements,

25 comprising means for defining a plurality of alternative network topologies to be analysed, means for evaluating, for each alternative topology, a probability of satisfying a maximum number n of flows, and means for evaluating a flow's relative cost for the alternative topologies,

30 allowing to understand which is the best configuration or evolution for the network under study.

Brief description of the drawings

The invention will now be described, by way of example only, with reference to the annexed figures of drawing, wherein:

Fig. 1 is a flow diagram of a method of designing a transport network realized according to the present invention;

Fig. 2 is a detailed flow diagram of a probability evaluation routine used in the method shown in Figure 1;

Fig. 3 is a block diagram of a first network topology considered for illustrating a method according to the present invention;

Fig. 4 is a block diagram of a second network topology considered for illustrating a method according to the present invention;

Fig. 5 is a graph showing a probability of satisfying a maximum number n of flows;

Fig. 6 is a graph showing a flow's unit cost as a function of the probability of satisfying a maximum number n of flows; and

Fig. 7 is a graph showing comparison results of a method/device realized according to the present invention.

Detailed description of a preferred embodiment of the invention

With reference to the flow diagram of figure 1, a network design and analysis method allowing to evaluate the flow's cost for different network structures will be described herein below.

As a first step (block 4 in diagram of figure 1) it is necessary to define a plurality of alternative network configurations, each configuration being defined by a plurality of network elements interconnected by a plurality of connections.

For each network under study, the following input data have to be specified:

- number of nodes/equipments inside the network;

- number and typologies of the links (real or
5 hypothetical) between nodes/equipments.

A first network configuration can be, for example, the configuration of an existing network which will be compared with a number of alternative network configurations, in case the design method is used for optimising an existing
10 network or node; otherwise the method according to the invention can be used as a design tool for designing a new network architecture or even a single node of a network.

Once a plurality, at least two, of network configurations X have been defined the methodology follows
15 the following main steps:

- evaluation (block 6 in figure 1) for the configurations under study, of the probability of satisfying a maximum number n of flows; this step calculates, for each alternative network configuration X_i,
20 a probability function $P(n)$ representing, for each maximum number n of routable flows, the probability of routing such a number of flows in the network configuration currently considered;

- evaluation (block 8 in figure 1) of a complexity
25 value, representative of a flow's unitary cost, for different network configurations; this step calculates, for each alternative network configuration, a complexity function $C_i(n)$, corresponding, in terms of costs, to a unit-cost-per-flow function, calculated as the ratio
30 between a sum of complexity factors, or costs, relative to the network elements of the network configuration currently considered and the probability function $P(n)$ previously obtained;

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- determination (block 10 in figure 1) of the best configuration; this step is performed by comparing each other the complexity, or unit-cost-per-flow, functions $C_i(n)$ of the alternative network configurations, for

5 choosing a network configuration having a lowest unit-cost-per-flow, or complexity, value.

The step of evaluation of the probability $P(n)$ of routing at maximum n flows (block 6 in figure 1) will now be described in detail, with reference to figure 2.

10 Once the number of nodes/equipments and the number of links existing between them has been defined, in order to compare different network structures, such structures are analysed under random traffic condition or under polarized traffic condition, depending from the features of the

15 network under study.

Considering a random traffic demand, a random number in the range between 1 and the number of nodes/equipments of the network is generated (block 26 in figure 2); this number represents the flow's origin (block 22 in figure 2).

20 A second random number, belonging to the same range but different to the first one, is then generated (block 28 in figure 2); this second number will be the flow's destination (block 24 in figure 2).

Otherwise, if a polarized traffic demand has to be

25 considered, different weights have to be assigned to one or more directions (a direction is the path between origin and destination), in the traffic generator (blocks 26 and 28 of figure 2).

Once the flow's origin and the destination (blocks 22

30 and 24 of figure 2) have been defined, the process tries to route it on the cheapest path, that's to say on the path using only one hop (block 30 figure 2). If this path is free, the flow is routed, a partial counter n_OK of maximum

routable flows is increased (block 32 figure 2), and a new
flow is generated (routine 20 is re-executed until no more
routable flows can be found). Otherwise, the process tries
to route the same flow on a more expensive path (i.e. a two
5   hops path, block 34 of figure 2, and so on, up to n-hops
path, block 36 of figure 2. When it is not possible
anymore to route a path inside the network's structure
under study, routine 20 terminates, and a maximum number of
flows routable n_OK is obtained.

10   The procedure of routine 20 is then repeated m times
(loop 40 of figure 2), where m is big enough in order to
obtain a valid statistical data, for example m=50000. Each
run of the routine generates a new value n_OK(i), with
i=1..m.

15   The values n_OK(i) are used for calculating the
probability function P(n), as the empirical probability of
an event can be defined as the ratio between the number of
favourable outcomes and the total number of outcomes:

$$P(n) = \frac{F(n)}{m}$$

20   where F(n) is the frequency of each maximum number n
of routable flows, and m is the number of times the
procedure has been repeated. The maximum number n of
routable flows corresponds to the value n_OK previously
determined.

25   The step previously described is repeated for every
network configuration X_i under evaluation, calculating, for
each configuration, a probability function $P_i(n)$. In this
way, the maximum number of flows routable inside the
network is evaluated for all network configurations.

30   Analysing the probability functions $P_i(n)$ it is
possible, as described in detail in the following, to
compare the different network configurations. Once the

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probability of routing at maximum n flows has been
evaluated for any different structures of the network under
study, in fact, it becomes possible to compare their costs
and advantages.

5   In order to do that, the method considers the number
of transmitting elements, or network elements, used in the
different network's structures analysed and their relative
complexity, or costs, for calculating a complexity function
$C_i(n)$ representing a unitary cost per flow for each network
10 configuration. The function $C_i(n)$, which is a function of
the maximum number of routable flows, corresponds to a
unit-cost-per-flow function and is defined as follows:

$$C_i(n) = \frac{\sum_{j=1}^{n.transmitting\,el.} transmitting\,el.\,(j) \cdot relative cost\,(j)}{P_i(n)}$$

Function $C_i(n)$ represents, for each alternative
15 network configuration X_i, the ratio between a sum of the
costs (relativecost(j)) relative to the network elements of
the network configuration currently considered, which are
proportional to the complexity of the same network
elements, and the corresponding probability function $P_i(n)$.

20   By the comparison, for the different network
configurations X_i under study, of the values of the
function $C_i(n)$, it becomes possible to understand which is
the best network configuration in terms of complexity, and
therefore in terms of costs (the configuration having a
25 lowest complexity, or unit-cost-per-flow, value).

In particular, in order to design or optimise the
network in view of future needs, in terms of maximum number
of routable flows on the network, the step of comparing the
unit-cost-per-flow functions $C_i(n)$ is performed calculating
30 the function $C_i(n)$ in correspondence of a particular
estimated maximum number n of routable flows. The estimated

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maximum number n of routable flows can be based, for example, on a forecast.

The method described above can be implemented in a device, whose structure is as well represented by the
5 diagram of figure 1, for designing a transport network comprising the following main units:

- a network configuration unit 4, for defining a first network configuration and at least one alternative network configuration;

10   - a probability evaluation unit 6, for calculating, for each network configuration X_i, a probability function $P_i(n)$ representing, for each maximum number n of routable flows, the probability of routing such a number of flows in the network configuration currently considered;

15   - a complexity, or unit-cost-per-flow, evaluation unit 8, for calculating, for each network configuration, a complexity function $C_i(n)$ calculated as the ratio between a sum of the costs relative to the network elements of the network configuration currently considered X_i and the
20 probability function $P_i(n)$;

- a comparison unit 10, for comparing the complexity functions $C_i(n)$ of the network configurations, for choosing a network configuration having a lowest complexity, or unit-cost-per-flow, value.

25   The method and device according to the present invention can be implemented as a computer program comprising computer program code means adapted to run on a computer. Such computer program can be embodied on a computer readable medium.

30   In order to understand the operation of the method/device, an example of application will now be described in detail. The alternative network configurations

considered are those shown in figure 3 and 4, a Mesh
topology and a Star topology connecting five Network
Elements NE1..NE5 inside a same node. It is supposed that,
for each Network Element, 24 ports are dedicated to connect
5 the elements each other, in the way described in Figures 3
and 4.

On the hypothesis of a random traffic demand, the
values of the probability $P(n)$ of routing at maximum n
flows for the two topologies considered are shown in the
10 graph diagram represented in Figure 5. The two curves 42,
44 represent, respectively, the probability to satisfy at
maximum n flows for the Mesh and for the Star topology.

Considering the relative costs shown in the following
table for the main transmitting elements of the network
15 under study, it is possible to evaluate the flow's unit
cost $C(n)$ for the two topologies under study. The
complexity factors of the transmitting elements are
proportional to the costs of the same transmitting
elements.

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Equipment	Relative cost
DXC	0.53
DXC's port	0.0004
Star's core	0.37
Port of the star's core	0.0002

The curves obtained for the flow's unit cost functions
$C(n)$ are shown in figure 6, wherein 46 represents the curve
relative to the Mesh topology and 48 represents the curve
25 relative to the Star topology.

In order to correctly analyse the curves of figure 6,
it is important to understand that, since the two
topologies have a different range of maximum number n of
flows routable, the comparison of the flow's unit cost $C(n)$

has to be done in the region in which both probability functions P(n) are defined (i.e. where P(n)>0). In the case shown, this condition corresponds to values of the maximum number of flows routable n in the range between 52 and 60,

5   as can be seen in figure 5.

The comparison of the flow's unit cost functions C(n) for the two topologies under study, in the region 52 <= n <= 60, is shown in figure 7.

The chart of figure 7 can be used for determining

10 three different regions, indicated by the black arrows 54, 56 and 58, showing different regions of decision.

In particular the chart shows that if one knows that, inside the network under study, it will not be necessary to route more than 55 flows, the Mesh topology will be more

15 economical, on the other hand, if it will be necessary to route, at maximum, between 56 and 58 flows, the two topologies will be equivalent, ultimately, if it will be necessary to route more than 58 flows, the Star topology will be more convenient than the Mesh one.

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